

Appl. No. 10/573,331
Amtd. Dated December 22, 2008
Reply to Office Action of June 25, 2008

Attorney Docket No. 81880.0142
Customer No.: 26021

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1-32. (Canceled)

33. (Currently amended) A multi-layer piezoelectric element comprising a stack formed by stacking piezoelectric layers and internal electrodes alternately one on another and external electrodes formed on a first side face and on a second side face of the stack, one of the adjacent internal electrodes being connected to the external electrode formed on the first side face and the other internal electrode being connected to the external electrode formed on the second side face,

wherein the metal composition contained in the internal electrodes contains ~~group VIII metal and group Ib metal of the periodic table as the main components silver as the main component and at least one of palladium and platinum~~, and contents of ~~the group VIII metal and the group Ib metal silver as the main component and at least one of palladium and platinum~~ are set so that proportion M1 (% by weight) of ~~the group VIII metal at least one of palladium and platinum~~ and proportion M2 (% by weight) of ~~the group Ib metal silver~~ satisfy the relations 0 < M1 ≤ 15, 85 ≤ M2 < 100 and M1 + M2 = 100,

wherein the external electrodes being made of a conductive material including silver as a main component and glass.

wherein the proportion of silver contained in electrically conductive material of the internal electrode near the junction with the external electrode is higher than the proportion of silver contained in electrically conductive material of the internal electrode located inside of the stack.

34-36. (Canceled)

37. (Currently amended) A multi-layer piezoelectric element comprising a stack formed by stacking piezoelectric layers and internal electrodes alternately one on another and external electrodes formed on a first side face and on a second side face of the stack, one of the adjacent internal electrodes being connected to the external electrode formed on the first side face and the other internal electrode being connected to the external electrode formed on the second side face,

wherein the internal electrodes being made of an electrically conductive material that contains silver as the main component and at least one of palladium and platinum.

wherein a resistance of the internal electrode device is higher than a resistance ρ_{Ag} of the device having the internal electrode of which metallic component consists solely of silver, and is lower than the resistance ρ_{Pd} of the device having the internal electrode of which metallic component consists solely of palladium,

wherein the external electrodes being made of a conductive material including silver as a main component and glass.

wherein the proportion of silver contained in electrically conductive material of the internal electrode near the junction with the external electrode is higher than the proportion of silver contained in electrically conductive material of the internal electrode located inside of the stack.

38. (Currently amended) The multi-layer piezoelectric element according to claim 33;

wherein a resistancee conductivity of the internal electrode is lower than a conductivity σ_{Ag} of the device having the internal electrode of which metallic component consists solely of silver, and is higher than a conductivity σ_{Pd} of the device having the internal electrode of which metallic component consists solely of palladium.

39. (Previously presented) The multi-layer piezoelectric element according to claim 33;

wherein 80% by volume or more of crystal grains formed from the metallic component that constitutes the internal electrode have particle size of $1\mu m$ or larger.

40. (Previously presented) The multi-layer piezoelectric element according to claim 33;

wherein an inorganic component is contained along with the metallic component in the internal electrode.

41. (Previously presented) The multi-layer piezoelectric element according to claim 40;

wherein the inorganic component contains perovskite type oxide consisting of $PbZrO_3$ - $PbTiO_3$ as the main component.

42. (Previously presented) The multi-layer piezoelectric element according to claim 33;

wherein the piezoelectric material contains perovskite type oxide as the main component.

43. (Previously presented) The multi-layer piezoelectric element according to claim 42;

wherein the piezoelectric material contains perovskite type oxide consisting of PbZrO_3 - PbTiO_3 as the main component.

44. (Previously presented) The multi-layer piezoelectric element according to claim 33;

wherein the temperature of firing the stack is in a range from 900 to 1000°C.

45. (Previously presented) The multi-layer piezoelectric element according to claim 33;

wherein the deviation in the composition of the internal electrode that is caused by the firing operation is 5% or less.

46. (Previously presented) The multi-layer piezoelectric element according to claim 35;

wherein the external electrode is formed from an electrically conductive material consisting mainly of silver and glass, and

wherein proportions of silver contained in the internal electrode and the external electrode are set so that the proportion X (% by weight) of silver contained in the electrically conductive material as a whole and the proportion Y (% by weight) of silver to the total weight of the electrically conductive material and glass contained in the external electrode satisfy conditions of $X \geq 85$ and $0.9 \leq X/Y \leq 1.1$.

47. (Previously presented) The multi-layer piezoelectric element according to claim 46;

wherein the internal electrode contains piezoelectric material, and

wherein the proportion Z (% by weight) of silver to the total weight of the internal electrode containing the piezoelectric material satisfies condition of $0.7 \leq Z/Y \leq 1.0$.

48. (Previously presented) The multi-layer piezoelectric element according to claim 46;

wherein the external electrode is formed from a porous electrically conductive material that has 3-dimensional mesh structure.

49. (Previously presented) The multi-layer piezoelectric element according to claim 46;

wherein void ratio of the external electrode is in a range from 30 to 70% by volume.

50. (Previously presented) The multi-layer piezoelectric element according to claim 46;

wherein the softening point ($^{\circ}\text{C}$) of the glass used in the external electrode is not higher than $4/5$ of the melting point ($^{\circ}\text{C}$) of the electrically conductive material that constitutes the internal electrode.

51. (Previously presented) The multi-layer piezoelectric element according to claims 50;

wherein the glass that constitutes the external electrode is amorphous.

52. (Previously presented) The multi-layer piezoelectric element according to claim 46;

wherein a thickness of the external electrode is smaller than a thickness of the piezoelectric layer that constitutes the stack.

53. (Canceled)

54. (Currently amended) The multi-layer piezoelectric element according to claim [[53]] 33;

wherein the proportion of silver contained in electrically conductive material of the internal electrode becomes higher toward the external electrode.

55. (Currently amended) The multi-layer piezoelectric element according to claim [[53]] 33;

wherein the proportion of silver contained in the electrically conductive material of the internal electrode is 85% by weight or higher.

56. (Currently amended) The multi-layer piezoelectric element according to claim [[53]] 33;

wherein the glass component is contained in the external electrode ~~exists in a~~ region substantially not more than 80% in thickness of the external electrode on the side of the surface of the stack.

57. (Currently amended) The multi-layer piezoelectric element according to claim [[53]] 33;

wherein the glass component contained in the external electrode contains lead oxide or bismuth oxide.

58. (Previously presented) The multi-layer piezoelectric element according to claim 33;

wherein the electrically conductive material of the internal electrode diffuses into the external electrode so as to form a neck in the joint between the internal electrode and the external electrode.

59. (Previously presented) The multi-layer piezoelectric element according to claim 33;

wherein a glass-rich layer is formed on the surface of the external electrode on the side thereof facing the piezoelectric layer.

60. (Currently amended) The A multi-layer piezoelectric element according to claim 33; comprising a stack formed by stacking piezoelectric layers and internal electrodes alternately one on another and external electrodes formed on a first side face and on a second side face of the stack, one of the adjacent internal electrodes being connected to the external electrode formed on the first side face and the other internal electrode being connected to the external electrode formed on the second side face,

wherein the metal composition contained in the internal electrodes contains group VIII metal and group Ib metal of the periodic table as the main components, and contents of the group VIII metal and the group Ib metal are set so that proportion M1 (% by weight) of the group VIII metal and proportion M2 (% by

weight) of the group Ib metal satisfy the relations $0 < M1 < 15$, $85 \leq M2 < 100$ and $M1 + M2 = 100$,

wherein the internal electrode contains voids and the voids occupy 5 to 70% of cross sectional area of the internal electrode.

61. (Previously presented) The multi-layer piezoelectric element according to claim 33;

wherein a groove is formed between the end of the other internal electrode and the external electrode on the first side face, with the groove being filled with an insulating material and a groove is formed between the end of the one internal electrode and the external electrode on the second side face, with the groove being filled with an insulating material, the insulating material having Young's modulus lower than that of the piezoelectric material.

62. (Previously presented) The multi-layer piezoelectric element according to claim 33; further comprising an electrically conductive assisting member formed from an electrically conductive adhesive, containing a metal mesh or a mesh-like metal sheet embedded therein, on the external surface of the external electrode.

63. (Previously presented) The multi-layer piezoelectric element according to claim 62;

wherein the electrically conductive adhesive is polyimide resin having electrically conductive particles dispersed therein.

64. (Previously presented) The multi-layer piezoelectric element according to claim 63;

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wherein the electrically conductive particles are silver particles.